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Dr. LEE, President, in the Chair.

The Rev. Thomas Pyne, Hook, near Kingston-on-Thames;
James McDowell, Esq., Perse Grammar School, Cambridge;
William Wray, Esq., 25 Torriano Terrace, Kentish Town;
C. H. Lake, Esq., Oxford House, King's Road, Chelsea;
Signor Julian Vertu, Lincoln;
John Kidd, Esq., Sherborne, Dorset; and
James Breen, Esq.,

were balloted for and duly elected Fellows of the Society.

An Account of Experiments on Solar Radiation.—Appendix describing the Method employed to discover the Influence of the Air in the Cooling of the Sun Thermometer X., and of Ascertaining the Correction required to be Applied to Observations of r, so as to reduce them to a Vacuum. By John James Waterston, Esq.

Fig. 2* is an upright section of the little apparatus or vacuum-bath. It consists of a cylindrical vessel of brass

* See last number of the *Notices*: the scale is 1 in. = 4 in.—ED.

coated internally with lamp-black. The lid was ground air-tight to the upper edge, and had a stuffing-box in the centre, through which the stem of the thermometer was passed. A stop-cock enabled a communication to be made with an air-pump. With a plentiful supply of lard to the stuffing-box and ground surfaces, a good vacuum could be maintained for a day unimpaired.

The time was measured by the beats of a clock: to register the number of these at each degree as the mercury of the thermometer descended, a scale of equal parts was prepared extending to 1000, and with distinguishing marks at each 5, 10, 50, and 100. Then with a pencil in the right hand over the scale and a magnifying glass in the left over the scale of the thermometer, I counted the beats, and when the mercury came to the line of a degree, made a mark on the scale of equal parts opposite the number of beats, and at the same time continued to count on; *e. g.* if 57 was the number when the mercury came to a line, a pencil-mark was made at 57 on the scale of equal parts, and the counting went on,—58, 59, &c. until the mercury came to the next line.

Thus, not a beat was lost from beginning to end, and the accuracy was only limited by the accuracy of the divisions on the scale of the thermometer. Indeed, this method is a severe test to the equality of the divisions, because the reciprocal of the differences in the number of the beats for each degree, if laid off as ordinates to the total number of beats, ought to range in a straight line, and any saw-like irregularities indicate inaccuracy in the divisions of the scale of the thermometer. To heat the bulb of the thermometer a funnel was placed over the small flame of a Bunsen; then holding the plate (having the thermometer fixed in its place) by means of the stop-cock, the bulb was brought over the top of the funnel until the mercury had risen to near the top of the scale. The plate was then quickly placed on the cylinder, communication made with the air-pump, and the air exhausted from the cylinder by 20 strokes, the capacity of the pump being about one-third that of the cylindrical vessel or vacuum-bath. The vessel thus exhausted was placed in a water-bath, the temperature of which was ascertained at the beginning and end; the difference seldom amounting to $\frac{1}{10}$th of a degree.

The following table exhibits two series of observations on the cooling of the sun thermometer, x, in the vacuum, and in air taken while the water-bath remained steady at 48°. This basal temperature being at an exact degree enables the rate of cooling to be studied easily without fractional parts or interpolation:—

Temp. X.	Beats in Vacuum.	r.	Beats in Air.	Temp. X.	Beats in Vacuum.	r.	Beats in Air.
90°		42°	0	90°		42°	
85°	0	37°	36	65°	323	17°	270
4	12	36		4	348	16	291
3	24	35		3	377	15	312
2	36	34		2	406	14	336
1	48	33		1	437	13	360
80	60½	32	78	60	470	12	385
9	73	31		9	510	11	414
8	86	30		8	549	10	448
7	100½	29		7	594	9	484
6	115	28		6	643	8	527
75	130½	27	129	55	704	7	576
4	145½	26		4	765	6	630
3	161	25		3	843	5	695
2	179½	24		2	...	4	780
1	197	23		1	...	3	
70	214	22	191	50	...	2	
9	235	21		9	...	1	
8	255	20		48	...	0	
7	276	19					
6	298	18					

Thus, 53, being the last observation of the vacuum cooling, corresponds with $r = 5°$; then

At $r = 5$ we have 843 beats
$r = 10$,, 549 ,,
$r = 20$,, 255 ,,
$r = 40$,, −32 ,,

Difference 294
,, 294
,, 287

Mean Difference 291·7

Again, beginning with $r = 7°$,

At $r = 7$ we have 704 beats
$r = 14$,, 406 ,,
$r = 28$,, 115 ,,

Difference 298
,, 291

Mean Difference 294½

And beginning with $r = 9$,

At $r = 9$ we have 594 beats
$r = 18$,, 298 ,,
$r = 36$,, 12 ,,

Difference 296
,, 286

Mean Difference 291

The numbers in the column of differences ought to be the same if the law of cooling in a vacuum is perfectly true, if the vacuum is complete, and if the graduation of the thermometer is correct. The difference between them is so small that the result must, I think, be deemed satisfactory.

Let us study the same differences with the cooling in air:—

At $r = 5°$ we have 695 beats		
	1st Difference 247	
$r = 10$,, 448 ,,		2d Difference 19
	,, 228	
$r = 20$,, 220 ,,		,, 22
	,, 206	
$r = 40$,, 14 ,,		
$r = 7°$ we have 576 beats		
	1st Difference 240	
$r = 14$,, 336 ,,		2d Difference 23
	,, 217	
$r = 28$,, 119 ,,		
$r = 9°$ we have 484 beats		
	1st Difference 230	
$r = 18$,, 254 ,,		2d Difference 20
	,, 210	
$r = 36$,, 44 ,,		

Thus, it appears that in air the cooling takes place in a ratio greater than r, the 1st difference of the times diminishing and the 2d difference slightly increasing between 247 and 210. The limiting value of the 1st difference must be 294 when $r = 0$, and 294 minus the 1st difference increases nearly as $\sqrt{r}$. An empirical formula constructed in conformity with this ratio cannot differ much from the observations.

Let Δ represent 1st difference and g a constant,

$$\Delta = 294 - g\sqrt{r} \quad \text{and} \quad g = \frac{294 - 247}{\sqrt{7\frac{1}{2}}} = 17{\cdot}162 = \frac{294 - 210}{\sqrt{27}} = \text{\&c. (nearly).}$$

Δ represents the logarithm of 2, so that c being a constant, we have $\log r = \frac{\Delta}{c}$. In the curve that represents the cooling in air we may assume a small arc of it to coincide with a true logarithmic curve or the curve of cooling in a vacuum, and we have to find the value of r, the ordinate of the true logarithmic curve at the given point.

The logarithmic curve is defined by the equation

$$c \log \frac{r_1}{r_0} = t_1 - t_0 = \frac{\Delta}{\log 2} \log \frac{r_1}{r_0}.$$

Let

$$r_0 = (r_1 - 0°{\cdot}1).$$

To find the value of r_v corresponding to a given r_a (r_v vacuum, r_a air), we require to compute the value of $t_1 - t_0$, employing $\Delta_a = 294 - g\sqrt{r}$ in the equation

$$\frac{\Delta_a}{\log 2} \log \frac{r_a}{(r_a - 0°{\cdot}1)} = t_1 - t_0;$$

then, with this value of $t_1 - t_0$, and with $\Delta_v = 294$, find the value of r_v in the equation

$$t_1 - t_0 = \frac{\Delta_v}{\log 2} \cdot \log \frac{r_v}{(r_v - 0°{\cdot}1)}.$$

The direct equation is

$$\Delta_a \{\log r_a - \log (r_a - 0°{\cdot}1)\} = \Delta_v \{\log r_v - \log (r_v - 0°{\cdot}1)\}$$

and

$$\frac{\Delta_a}{\Delta_v} = 1 - \frac{g}{294}\sqrt{r_a} = 1 - \frac{\sqrt{r_a}}{17{\cdot}131}.$$

Hence r_v may be ascertained by inspecting the differences of a table of logarithms; and it was from these that a scale was constructed for reducing the values of r taken in air to what they would be if taken in a vacuum, where the emission of heat was by radiation alone.

The cooling of the sun thermometer in air when fixed in its place in the tube, as in fig. 1, was found to be exactly the same as when fixed in the cylinder, fig. 2, unexhausted.

A chemical thermometer with cylindrical reservoir was tried in the vacuum-bath, and the cooling was found to take place exactly in the logarithmic curve. It is difficult to adjust the vacuum-bath in time to observe a high value of r, but good observations were obtained from $r = 190°$ downwards; so there is little doubt that the law of cooling by radiation is general and independent of the shape of the cooling body. I purpose extending these observations with different surfaces. One result is interesting, as showing the perfect reciprocity of the radiation, viz. a gilt bulb radiating against a blackened metallic surface loses heat at the same rate as a blackened bulb against a bright metallic surface; the rate being slower than when both are blackened.

Another fact that it is well to keep in view is that, although the uncoated glass bulb radiates as quickly as the same coated with black, it does not absorb the incident rays of heat to the same degree; nearly one half being reflected without entering the glass.

Observations on Solar Radiation.

1861.	Apparent Time. Latitude, 55° 58′ N. Longitude, 0h 12m 44s W.	Observed Values of r.	Ditto corrected for Talc Film.	Correction to Reduce to a Vacuum.	Value of r Reduced to a Vacuum.	Reciprocal of Ditto.	Apparent Altitude of Sun's Centre.	Cosecant of Apparent Zenith Distance.	Remarks
		r_o	r_a	p	r_v	$\frac{1}{r_v}$	App. Alt.		
	h m	°	°	°	°		° ′		
July 28	4 25 P.M.	17·5	20·6	+7·4	28·0	·0357	28 49	2·075	Bulb coated with lamp-black and turpentine; surface moist.
	4 36	16·5	19·5	6·8	26·3	·0380	27 16	2·183	
	4 56	15·5	18·3	6·2	24·5	·0408	24 30	2·411	
	5 26	14·0	16·5	5·2	21·7	·0461	20 19	2·880	
	6 18	13·2	15·5	4·7	20·2	·0495	13 11	4·385	
	7 26	7·2	8·5	1·7	10·2	·0980	4 27	12·888	
30	6 36 P.M.	11·8	13·9	+3·9	17·8	·0562	10 41	5·394	
	6 45	10·8	12·7	3·3	16·0	·0625	9 12	6·255	
	7 13	6·6	7·8	1·4	9·2	·1087	5 44	10·010	
31	Noon	23·0	27·2	+11·4	38·6	·0259	52 20	1·263	Extra favourable conditions.
	5 41 P.M.	15·0	17·7	5·8	23·5	·0425	17 38	3·301	Ditto.
	6 6	14·0	16·5	5·2	21·7	·0461	14 3	4·119	
	6 29	13·0	15·3	4·6	19·9	·0502	11 6	5·194	
	7 18	9·0	10·6	2·5	13·1	·0763	4 36	12·47	
	7 34	6·0?	7·1	1·3	8·4	·1190	2 52		From July 31, noon to Aug. 5, noon the bulb coated with China ink and gum solution; surface dry.
Aug. 1	9 51 A.M.	20·5	+?24·2	+9·5	33·7	·0297	44 58	1·415	
4	11 1 A.M.	20·0	23·6	9·1	32·7	·0306	49 35	1·313	
	6 36 P.M.	11·3	13·4	3·6	17·0	·0588	9 15	6·221	
5	Noon	20·2	23·8	9·2	33·0	·0303	51 0	1·287	Extra favourable.
B	3 44 P.M.	11·3	13·3	3·6	16·9	·0592	33 14	1·825	Bulb uncoated.
B	4 30	9·7	11·4	2·7	14·1	·0709	27 10	2·190	Ditto.

All the above, taken with thermometer Y in the sun, and its correction for air, has been assumed to be the same as that experimentally determined for thermometer X in the subsequent observations.

In the following observations the thermometer in sun was X, with bulb coated with China ink:—

1861.		r_o	r_a	p	r_v	$\frac{1}{r_v}$	App. Alt.	cosec.	
	h m	°	°	°	°		° ′		
Aug. 9	3 34 P.M.	14·4	17·0	+5·5	22·5	·0444	33 7	1·830	
10	8 50 A.M.	15·2	17·9	+5·9	23·8	·0420	35 56	1·704	Taken from a consecutive series of 18 observations.
	9 8	15·5	18·3	6·1	24·4	·0410	38 5	1·621	
	9 23	16·2	19·1	6·6	25·7	·0389	39 48	1·562	

1861.	h m		r_o	r_a	p	r_v	$\frac{1}{r_v}$	App. Alt.	cosec.	
			°	°	°	°		° ′		
13	4 56	P.M.	12·8	15·1	+4·5	19·6	·0510	21 1	2·787	Not less, perhaps greater value of r.
	6 56		4·8	5·7	0·9	6·6	·1515	4 37	12·42	
	7 27		2·2	2·6	0·3	2·9	·3448	0 53		Sunset.
15	6 1	P.M.	9·5	11·2	2·7	13·9	·0719	11 25	5·05	
	7 4		3·8	4·5	0·6	5·1	·1961	3 4	18·69	
16	5 16	A.M.	4·4	5·2	0·8	6·0	·1667	5 29	10·465	Sun rises perfectly clear of clouds.
	9 39		14·6	17·2	5·6	22·8	·0439	39 51	1·561	
	11 3		15·0	17·7	5·8	23·5	·0425	46 20	1·382	
21	7 20	A.M.	9·8	11·6	2·9	14·5	·0690	19 0	3·071	
	7 40		10·7	12·6	3·3	15·9	·0629	21 45	2·698	
	8 0		11·6	13·7	3·8	17·5	·0571	24 29	2·413	
	8 20		12·3	14·5	4·2	18·7	·0535	27 9	2·191	Consecutive series graphically projected and equalised.
	8 40		13·0	15·3	4·6	19·9	·0502	29 45	2·015	
	9 0		13·5	15·9	4·9	20·8	·0481	32 14	1·874	
	9 20		13·8	16·2	5·0	21·2	·0472	34 37	1·760	
	9 40		14·1	16·6	5·3	21·9	·0457	36 50	1·668	
	h m s									
20	6 21 16	P.M.	6·6	7·7	+1·4	9·1	·1099	7 21	7·817	
	6 23 16		6·5	7·6	1·4	9·0	·1111	7 4	8·128	
	6 24 31		6·4	7·5	1·4	8·9	·1124	6 55	8·304	
	6 26 16		6·1	7·2	1·3	8·5	·1177	6 41	8·592	
	6 27 16		6·0	7·1	1·2	8·3	·1205	6 33	8·767	Consecutive series not equalised.
	6 28 36		6·1	7·2	1·3	8·5	·1177	6 22	9·018	
	6 31 0		5·7	6·7	1·1	7·8	·1282	6 2	9·514	
	6 37 16		4·8	5·7	0·8	6·5	·1538	5 12	11·034	
	6 39 0		4·7	5·6	0·8	6·4	·1562	4 59	11·512	
	Small cloud passes over the sun.									
	6 43 56		3·4	4·0	0·5	4·5	·2207	4 22	13·134	
	6 45 46		3·3	3·9	0·5	4·4	·227	4 5		
	6 47 16		3·2	3·8	0·5	4·2	·235	3 54		
	6 49 16		3·0	3·6	0·5	4·0	·249	3 38		
	6 51 0		2·8	3·3	0·4	3·7	·272	3 25		
	6 52 16		2·7	3·1	0·3	3·5	·287	3 15		
	6 54 0		2·4	2·9	0·3	3·2	·312	3 2		
	6 55 45		2·2	2·6	0·3	2·9	·348	2 48		
	6 58 46		1·9	2·2	0·2	2·4	·408	2 30		
	7 1 16		1·6	1·9	0·2	2·1	·483	2 7		
	7 4 0		1·1	1·3	0·1	1·4	·714	1 48		
28	Noon		12·5	14·8	4·3	19·1	·0524	43 42	1·447	
	0 44	P.M.	13·2	...	...	...	...	...	...	r sensibly augments after culmination.

In the following, thermometer T was in sun, with its bulb coated with lamp-black in gold size:—

1861.	h	m	r_0	r_a	p	r_v	$\frac{1}{r_v}$	App. Alt.	cosec.
			°	°	°	°		° ′	
Aug. 6	8	7 A.M.	16·2	19·1	6·6	25·7	·0389	31 17	1·926
	9	8	18·0	21·2	7·7	28·9	·0346	42 21	1·484
	9	32	18·3	21·6	8·0	29·6	·0338	45 12	1·409

Note.— Referring to the method of computing the Sun's potential temperature, described in the proceedings of the Society for March 1860, and employing the same rule with R, the extra atmospheric value of r equal to 70° at Earth's mean distance, we arrive at 12,880,000° as the potential temperature of its radiating surface.*

If we expose the flame of a bat's-wing-jet to one ball of a differential thermometer, the effect is the same, whether the broad side or the narrow side of the flame is presented, as I have found on trial. Now the potential temperature being equal to the product of r by the reciprocal of the angular space occupied by the flame, it is in the one case about five times greater than in the other. In the same way we might compute the potential temperature of an angular space occupied by many thousand flames placed one behind the other, extending in a line from the observer, and probably we should find it cumulative in the ratio of the number of flames.

From observations I have made on gas flames with the radiation meter, fig. 1, it would seem to require about 4000 bat's-wing-flames ranged behind each other to give a potential equal to that of the Sun.

If the upper radiating matter of the Sun is in any degree transparent or permeable to radiation from lower strata, it is obvious that the *actual* temperature may thus be much below the *potential.*

26 *Royal Crescent, Edinburgh, November* 25, 1861.

Note on a Theorem of Jacobi's, in relation to the Problem of Three Bodies. By A. Cayley, Esq.

The following theorem of Jacobi's (*Comptes Rendus*, t. iii., p. 61 (1836)) has not, I think, found its way in an explicit form into any treatise of physical astronomy. The theorem is as follows, viz. "Consider the movement of a point without mass round the Sun, disturbed by a planet the orbit of which

* There is a typographical error in the *Monthly Notices*, page 201, line 32; for $x = 918000$, read $x = 9{,}180{,}000$.

is circular. Let $x\,y\,z$ be the rectangular co-ordinates of the disturbed body, the orbit of the disturbing planet being taken as the plane of $x\,y$, and the Sun as the centre of co-ordinates; let a' be the distance of the disturbing planet, $n'\,t$ its longitude, m' its mass, M the mass of the Sun: then we have, *rigorously*,

$$\frac{1}{2}\left[\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2+\left(\frac{dr}{dt}\right)^2\right]-n'\left(x\frac{dy}{dt}-y\frac{dx}{dt}\right)$$

$$=\frac{\mathrm{M}}{(x^2+y^2+z^2)^{\frac{1}{2}}}+m'\left\{\frac{1}{(x^2+y^2+z^2-2a'(x\cos n't+y\sin n't)+a'^2)^{\frac{1}{2}}}\right.$$

$$\left.-\frac{x\cos n't+y\sin n't}{a'^2}\right\}+\mathrm{C}.$$

This is therefore a new integral equation, which, in the problem of three bodies, subsists, as regards the terms independent of the excentricity of the disturbing planet, and which is rigorous as regards all the powers of the mass of such planet. In the *Lunar Theory* the Earth must be substituted in the place of the Sun, and the Sun taken as the disturbing planet."

To prove the theorem, as expressed in polar co-ordinates, I take the equations of motion in the form in which I have employed them in my "Memoir on the Theory of Disturbed Elliptic Motion" (*Memoirs*, vol. xxvii. p. 1 (1859)), viz.

$$\frac{d}{dt}\frac{dr}{dt}-r\cos^2 y\left(\frac{dv}{dt}\right)^2-r\left(\frac{dy}{dt}\right)^2+\frac{n^2a^3}{r^2}=\frac{d\Omega}{dr},$$

$$\frac{d}{dt}\left(r^2\cos^2 y\frac{dv}{dt}\right)=\frac{d\Omega}{dv},$$

$$\frac{d}{dt}\left(r^2\frac{dy}{dt}\right)+r^2\cos y\sin y=\frac{d\Omega}{dy},$$

where

$$\Omega=m'\left\{\frac{1}{\sqrt{r^2+r'^2-2rr'\cos \mathrm{H}}}-\frac{r\cos \mathrm{H}}{r'^2}\right\};$$

or, since $\cos \mathrm{H}=\cos y\cos(v-v')$, and the Sun is considered as moving in a circular orbit (i.e. $r'=a'$, $v'=n'\,t$), we have

$$\Omega=m'\left\{\frac{1}{\sqrt{r^2+a'^2-2ra'\cos y\cos(v-n't)}}-\frac{r\cos y\cos(v-n't)}{a'^2}\right\};$$

so that Ω is a function of r, v, y and of t, which last quantity enters only in the combination $v - n't$. Hence the complete differential coefficient of Ω is

$$\frac{d(\Omega)}{dt} = \frac{d'\Omega}{dt} - n'\frac{d\Omega}{dv},$$

where $\frac{d'\Omega}{dt}$ denotes, as usual, the differential coefficient in regard to the time, in so far as it enters through the co-ordinates r, v, y of the disturbed body.

We have, as usual,

$$\frac{d}{dt}\frac{dr^2 + r^2(\cos^2 y\, dv^2 + dy^2)}{dt^2} = \frac{d'\Omega}{dt};$$

but from the foregoing equation,

$$\frac{d'\Omega}{dt} = \frac{d(\Omega)}{dt} + n'\frac{d\Omega}{dv}$$

$$= \frac{d(\Omega)}{dt} + n'\frac{d}{dt}\left(r^2\cos^2 y\frac{dv}{dt}\right);$$

and, substituting this value, transposing, and integrating, we have

$$\left(\frac{dr}{dt}\right)^2 + r^2\left\{\cos^2 y\left(\frac{dv}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2\right\} - n'r^2\cos^2 y\frac{dv}{dt} = \Omega + C,$$

which is Jacobi's equation expressed in terms of the co-ordinates r, v, y.

M. de Pontécoulant, in his *Lunar Theory* (1846), where the solar excentricity is neglected, writes (p. 91),

$$\int d'\mathrm{R} = \mathrm{R} + m\int\frac{d\mathrm{R}}{dv}dt,$$

($n' = m\,n = m$, since n is there put equal to unity); and combining this with the equation (p. 43),

$$\frac{r^2 dv}{(1+s^2)\,dt} = h + \int\frac{d\mathrm{R}}{dv}dt,$$

we have

$$\int d'\mathrm{R} = \mathrm{R} - mh + \frac{mr^2 dv}{(1+s^2)\,dt};$$

and substituting this value of $\int d'\mathrm{R}$ in the integral of *Vis Viva* (p. 41),

$$\left(\frac{dr}{dt}\right)^2 + \frac{r^2\,dv^2}{(1+s^2)\,dt^2} + \frac{r^2\,ds^2}{(1+s^2)^2\,dt^2} - \frac{2}{r} + \frac{1}{a} = 2\int d'\mathrm{R},$$

we have what is, in fact, Jacobi's equation.

A Third Memoir on the Problem of Disturbed Elliptic Motion. By A. Cayley, Esq. (Abstract.)

The object of the Memoir is to obtain the differential equations for determining

r, the radius vector,
v, the longitude,
y, the latitude,

of the disturbed body, when the last two co-ordinates are measured in respect to an arbitrarily varying plane (which, however, to fix the ideas, is called the variable ecliptic) and departure-point, or origin of longitudes therein. This is very readily effected by means of an expression for the *Vis-Viva* function given in my "Supplementary Memoir on the Problem of Disturbed Elliptic Motion," *Mem. Roy. Ast. Soc.*, vol. xxviii. pp. 217–234 (1859).

Neglecting the squares of the variations of the variable ecliptic, and also the products of the variations by sin y or $\frac{dy}{dt}$, then (as might be expected) it is found that the equations for r and v are the same as for a fixed ecliptic, and the equation for y is found in a simple form, which is ultimately reduced to coincide with that obtained for the lunar theory by Laplace in the seventh book of the *Mécanique Céleste*, and which is used by him to show that the effect of the variation of the ecliptic on the latitude of the Moon (as measured from the variable ecliptic) is insensible. And it is shown conversely how the approximate formula of the Memoir may be obtained by a process similar to that made use of in the *Mécanique Céleste*.

On the Circularity of the Sun's Disk. By G. B. Airy, Esq., Astronomer Royal.

It has been proposed lately to prepare an apparatus for the purpose of examining whether the Sun's disk is really circular, and, in particular, for ascertaining whether the diameters nearly perpendicular to the ecliptic are equal to those nearly parallel to the ecliptic. I would not by any means discourage the trial of such apparatus, but I would unhesitatingly express my opinion that the result of the trial would be to show whether the apparatus is or is not trustworthy, and not to give any new information regarding the measure of the Sun's diameters in any degree comparable to that which we already possess.

Perhaps few persons except professional astronomers are aware of the enormous amount of evidence which already exists in reference to the values of the Sun's diameters, and of the way in which this evidence is growing every day in the ordinary routine of meridional observations. To make this fully understood, I will here explain what is prepared in the *Nautical Almanac*, what is observed at the Royal Observatory, how the observations are reduced, and how the comparison of the reduced observations with the numbers of the *Nautical Almanac* bears upon the subject now before us.

For the calculations of the *Nautical Almanac*, an assumption is made as to the numerical value of the Sun's diameter, as seen when the Earth is at its mean distance from the Sun. It matters not whether this assumed diameter is or is not correct, provided that it be used consistently in all the calculations of each year; and it matters not whether it be or be not changed from year to year, provided that each volume contain a statement of the assumed diameter which has actually been used in the calculations of that volume. Thus the assumed value of Sun's diameter, as seen at Earth's mean distance, in the *Nautical Almanacs* from 1836 to 1852, was $32' 1''.80$; that in the subsequent *Nautical Almanacs* is $32' 3''.64$.

With the diameter thus assumed, two sets of numbers are computed in the *Nautical Almanac*. One is, the apparent diameter (or semidiameter) of the Sun at noon on every day; this is found by merely altering the assumed diameter in the inverse proportion of the Earth's varying distance from the Sun. The other is, the duration of passage of the Sun's diameter across the meridian, or the measure of the sidereal time which elapses between the passage of the Sun's western limb and its eastern limb; this is found, from the apparent diameter of the day, by introducing the consideration of the Sun's declination, and of the Sun's motion in right ascension. And, these numbers being prepared, it is evident that we have elements which correspond very closely with facts that may be

observed, the elements being essentially based on the supposition that the Sun's disk is circular.

Corresponding to these two classes of computed elements, we have two classes of facts observed at the Royal Observatory and at other Observatories. One is, the zenith distance of the Sun's upper limb and that of the Sun's lower limb. When each of these is corrected separately for refraction and parallax, the true results of geocentric observation are obtained; and the difference between them gives the observed *vertical* diameter of the Sun on the day of observation. The other is, the sidereal time shown by the transit-clock at the instant of transit of the Sun's western limb, and that at the transit of the Sun's eastern limb; the difference between these gives the observed duration of passage of the Sun's *horizontal* diameter across the meridian on the day of observation.

Now if we compare each of these numbers separately (namely, the observed vertical diameter and the observed duration of passage of horizontal diameter) with the corresponding numbers in the *Nautical Almanac*, and if we omit consideration of chance-errors of observation, the effect of which may be supposed to be nearly eliminated in the mean of many observations, the following results ought to hold:—If the Sun's disk is really circular, and if the *Nautical Almanac* assumed diameter at mean distance is correct, then the observed vertical diameter will agree with the *Nautical Almanac* diameter for the day, and the observed duration of passage will agree with that of the *Nautical Almanac*. If the Sun's disk is really circular, but the assumed diameter incorrect, then neither of the compared measures will agree with the corresponding computation of the *Nautical Almanac;* each discordance (one of vertical diameter, the other of duration of passage of horizontal diameter) will indicate a numerical value of correction to be applied to the assumed diameter; but the two numerical values will absolutely agree. But if the Sun's disk is not really circular, then it is impossible that the comparison of observed vertical diameters on the one hand, and of observed durations of passage of horizontal diameters on the other hand, with elements computed on the supposition that the Sun is circular, can indicate the same correction to the assumed semidiameter.

All that is necessary, therefore, for ascertaining whether the Sun's horizontal diameter and the Sun's vertical diameter are equal, is, every day to compare the Sun's observed vertical diameter with the *Nautical Almanac* diameter, and the observed duration of passage of Sun's horizontal diameter with the *Nautical Almanac* duration, and to infer separately from these the correction to be made to the *Nautical Almanac* assumed diameter. If the two results agree, the horizontal and vertical diameters are equal.

Now these comparisons are made every day in the routine of the Royal Observatory, and their results will be found in

one of the late sections of each volume of the printed *Greenwich Observations*, as well as in the more extensively distributed *Results of the Greenwich Observations*, which contain that section; and the means of the numbers for each year are given in the Introduction to each volume. By extracting these numbers, the following table is formed. I have thought it necessary to divide the table into three parts, distinguished by the following circumstances:—From 1836 to 1850, the 4-inch telescope (I believe Dollond's) of the Mural-Circle was used for the vertical diameters, and the 5-inch telescope (Dollond's) of the Transit for the horizontal passages; the diameter used in the computations of the *Nautical Almanac* was $32'\,1''{\cdot}80$. Through 1851 and 1852, the 8-inch telescope (Simms') of the Transit-Circle was used for both measures, the *Nautical Almanac* assumed diameter being still $32'\,1''{\cdot}80$. From 1853 to 1860, the telescope of the transit-circle was used for both measures, but the *Nautical Almanac* assumed diameter was $32'\,3''{\cdot}64$.

Apparent Errors of the Duration of Passage of the Sun's Horizontal Diameter, and of the Sun's Vertical Diameter, as computed in the Nautical Almanac.

Year.	No. of Obs. of Horizontal Diameter.	Mean Value of N.A. − Ob.	No. of Obs. of Vertical Diameter.	Mean Value of N.A. − Ob.
		s		s
1836	104	−0·17	116	−1·50
1837	92	−0·18	122	−1·85
1838	108	−0·14	115	−1·53
1839	103	−0·14	114	−0·94
1840	104	−0·18	112	−1·60
1841	102	−0·14	109	−1·32
1842	116	−0·14	121	−1·54
1843	99	−0·14	107	−1·84
1844	102	−0·18	117	−1·50
1845	100	−0·17	113	−1·32
1846	92	−0·10	101	−2·09
1847	89	−0·05	89	−2·98
1848	94	−0·06	102	−2·06
1849	103	−0·11	101	−2·40
1850	94	−0·11	86	−2·18
1851	87	−0·08	106	−0·71
1852	103	−0·12	112	−1·39
1853	78	0·00	86	+0·58
1854	109	+0·09	111	+1·29
1855	84	+0·07	93	+0·65

Year.	No. of Obs. of Horizontal Diameter.	Mean Value of N.A.—Ob.	No. of Obs. of Vertical Diameter.	Mean Value of N.A.—Ob.
		s		″
1856	104	+0·10	109	+1·17
1857	113	+0·07	123	+0·99
1858	126	+0·07	132	+0·92
1859	109	+0·08	125	+0·99
1860	72	+0·09	72	+1·64

If we take the sums of the numbers of observations and the means of the errors, and if we remark that the mean error of the horizontal diameter in arc may be obtained from the mean error of the duration of passage without sensible error by multiplying by 14, we obtain the following numbers:—

Period.	No. of Obs.	Mean Error of N.A. Duration of Passage.	Mean Error of N.A. Horizontal Diameter.	No. of Obs.	Mean Error of N.A. Vertical Diameter.
		s	″		″
1836 to 1850	1502	−0·134	−1·88	1625	−1·78
1851 and 1852	190	−0·100	−1·40	218	−1·05
1853 to 1860	795	+0·071	+0·99	851	+1·03

If we change the signs of these errors, to form corrections, and apply them to the assumed diameter at mean distance of the Earth from the Sun (namely, 32′ 1″·80 to the end of 1852, and 32′ 3″·64 from the beginning of 1853), to produce a corrected diameter of the Sun at mean distance, we form the following table:—

Instruments employed.	Period.	No. of Obs.	Corrected Horizontal Diameter.	No. of Obs.	Corrected Vertical Diameter.
			′ ″		′ ″
Transit and Mural Circle ...	1836 to 1850	1502	32 3·68	1625	32 3·58
Transit Circle ...	{1851 and 1852}	{190}	{32 3·20}	{218}	{22 2·85}
	{1853 to 1860}	{795}	{32 2·65}	{851}	{32 2·61}
	Mean 1851 to 1860	985	32 2·76	1069	32 2·66

Thus the observations with both classes of instruments, in aggregate number 2487 for horizontal diameter and 2694 for vertical diameter, agree in showing that the horizontal diameter exceeds the vertical diameter by only 0″·1, a quantity smaller than we can answer for in these or in any other methods of observation.

A consideration of the number and excellence of the observations fully supports the view which I have stated in introducing this subject: that the only result which could be deduced from the trial of new apparatus would be to test the apparatus, but not to add to the certainty of the conclusion as to the equality of diameters.

The diameter adopted now in the *Nautical Almanac* was inferred from observations made with the Transit and Mural Circle, and therefore agrees very closely with that here deduced from the use of those instruments. That obtained with the Transit-Circle is less by $0''.93$.

Royal Observatory, Greenwich,
Dec. 28th, 1861.

Table of Comparative Number of Observations of Small Planets. By the Astronomer Royal.

For my own guidance, in arranging the course of observations of the Royal Observatory, I lately thought it necessary to draw out a Table exhibiting the comparative number of observations of the Small Planets between *Mars* and *Jupiter*, on the one hand, as made at all Observatories (in the aggregate) except that of Greenwich, and on the other hand as made at Greenwich. For this purpose, I fixed upon the year 1858, as the latest for which I might presume all observations to be published; and my Assistant, Mr. Carpenter, examined every record to which I have access. The result may, perhaps, be interesting to the Society.

For Small Planets discovered before the middle of 1857.

Name of Planet.	Number of Observatories.	Number of Observations. Equatoreal.	Number of Observations. Meridional.	Observatory, Greenwich.	Number of Meridional Observations.
Ceres ①	2	0	21	,,	22
Pallas ②	2	0	12	,,	29
Juno ③	2	0	24	,,	27
Vesta ④	3	0	24	,,	31
Hebe ⑥	4	0	11	,,	19
Iris ⑦	5	14	13	,,	21
Flora ⑧	7	13	47	,,	23

Name of Planet.	Number of Observatories.	Number of Observations. Equatoreal.	Number of Observations. Meridional.	Observatory, Greenwich.	Number of Meridional Observations.
Metis (9)	1	0	2	,,	16
Hygeia (10)	0	0	0	,,	1
Parthenope (11)	3	4	10	,,	13
Egeria (13)	4	7	8	,,	17
Irene (14)	0	0	0	,,	6
Eunomia (15)	4	1	29	,,	22
Psyche (16)	5	18	7	,,	11
Thetis (17)	0	0	0	,,	1
Melpomene (18)	5	10	4	,,	21
Fortuna (19)	4	6	6	,,	22
Massilia (20)	6	14	19	,,	21
Lutetia (21)	1	5	0	,,	11
Calliope (22)	2	6	2	,,	8
Thalia (23)	6	4	16	,,	18
Themis (24)	6	25	8	,,	7
Phocæa (25)	1	1	0	,,	0
Proserpine (26)	5	19	4	,,	6
Euterpe (27)	5	6	33	,,	16
Bellona (28)	1	34	0	,,	0
Amphitrite (29)	5	6	9	,,	24
Urania (30)	5	20	6	,,	22
Pomona (32)	2	8	0	,,	4
Polyhymnia (33)	1	4	0	,,	0
Atalanta (36)	1	1	0	,,	0
Fides (37)	4	16	0	,,	0
Leda (38)	3	10	0	,,	2
Lætitia (39)	4	12	11	,,	32
Daphne (41)	1	1	0	,,	0
Iris (42)	0	0	0	,,	2
Ariadne (43)	3	14	0	,,	11
Nysa (44)	3	13	1	,,	4
	Sum	292	327		490

For Small Planets discovered after the middle of 1857.

Name of Planet.	Number of Observatories.	Number of Observations. Equatoreal.	Meridional.	Observatory, Greenwich.	Number of Meridional Observations.
Eugenia (45)	3	11	0	,,	0
Aglaia (47)	3	20	0	,,	0
Doris (48)	2	11	0	,,	0
Pales (49)	2	11	0	,,	0
Virginia (50)	3	14	0	,,	0
Nemausa (51)	5	57	0	,,	7
Europa (52)	10	62	17	,,	7
Calypso (53)	8	50	0	,,	0
Alexandra (54)	6	40	0	,,	2
Pandora (55)	7	83	0	,,	3
	Sum	359	17		19

It appears from this table that the observations made in the first year of a planet's discovery are almost exclusively extrameridional; but that in subsequent years the meridional observations slightly preponderate. And with regard to these (on which probably the accurate theory and even the permanent retention of planets in the list of our solar system will ultimately depend), it appears that a single Observatory of established regularity of system contributes a greater number of observations than the aggregate of all the others. As regards Greenwich, the increase in the number of small planets has now made it necessary to diminish the attention given to each; but it is probable that the ratio for the different Observatories will not be materially altered.

It appears necessary, therefore, that Observatories of fixed system should still retain these bodies in the list of those to be regularly followed. The observations, however, are extremely onerous, and it is much to be wished that they could be somewhat distributed. Hitherto my efforts to effect an arrangement for this purpose have entirely failed.

Royal Observatory, Greenwich,
1861, *December* 19.

Results of Meridional Observations of Small Planets; and Phenomena of Jupiter's Satellites; observed at the Royal Observatory, Greenwich, during the month of December, 1861.

(*Communicated by the Astronomer Royal.*)

Victoria (12).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Dec. 2	10 0 17·5	2 47 10·45	73 39 49·17
5	9 46 38·3	2 45 18·73	73 59 10·78
19	8 46 25·3	2 40 7·65	75 9 7·65

Irene (14).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Dec. 2	9 14 48·4	2 1 33·86	87 6 14·49
5	9 1 34·2	2 0 7·17	87 0 49·32

Europa (52).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Dec. 2	7 49 48·3	0 36 19·82	95 34 18·52

All the observations of N.P.D. have been corrected for refraction and parallax.

No occultations of Stars by the Moon were observed.

Phenomena of Jupiter's Satellites.

Day of Observation. 1861.	Satellite.	Phenomenon.	Mean Solar Time h m s	Observer.
Dec. 1	III	Ecl. reappearance (*a*)	14 27 24·3	C.
8	III	Ecl. disappearance	15 6 42·7	R.
8	III	Ecl. reappearance	18 23 34·1	R.
13	IV	Egress first cont. (*b*)	18 33 29·4	M. D.
13	IV	,, last cont. (*b*)	18 38 38·6	M. D.

(*a*) Unsatisfactory from cloud. (*b*) The planet's image much diffused.

The initials C., M. D., and R., are those of Mr. Criswick, Mr. Dolman, and Mr. Roberts.

Observations in Australia of the Transit of Mercury of the 12th November, 1861.

Mr. Scott, in a letter dated Observatory, Sydney, November 22d, 1861, writes:—

"The transit of *Mercury* which occurred on the 12th instant was only partially observed, on account of the cloudy state of the sky. The time of internal contact was $3^h\ 24^m\ 34^s$ Sydney mean time. The egress occurred after sunset."

And he encloses the following notice, received from Mr. Todd, at Adelaide:—

"I make time of total ingress, $2^h\ 34^m\ 12^s$.

	h	m	s
First contact, egress.....	6	30	29
Last contact, egress.....	6	32	19

"The first two may be considered good, especially the ingress. The last is uncertain, the Sun being low down and boiling."

Mr. Ellery, in a letter dated Observatory, Williamstown, Victoria, November 25th, 1861, writes:—

"We observed the ingress and a portion of the transit of *Mercury* across the Sun's disk on the 12th instant.

"It was cloudy most of the day, but the weather cleared up about 1 P.M., leaving us an almost clear sky until some time after the ingress of the planet. The egress took place after sunset to us.

"I observed the first contact, or rather *indentation*, at $2^h\ 58^m\ 2^s$. The first glimpse I got of the notch I estimated, by its subsequent motion, to be about 8^s after the first contact had taken place. The internal contact was lost on account of a passing cloud.

"As I possessed no other than a rough position-micrometer, I could make no measures during the transit."

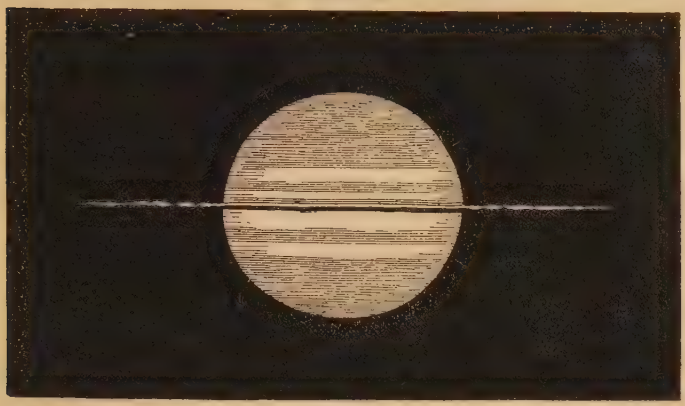
The longitude of the observatory is $9^h\ 39^m\ 40^s{\cdot}01$ E., lat. $37^\circ\ 52'\ 8''$ S.

Note on Two Drawings of Saturn. By Capt. W. S. Jacob.

Two drawings of *Saturn*, by Captain Jacob, were exhibited at the meeting in December. Captain Jacob writes : —

"No. 1 was taken on the morning of November 12th, shortly before the disappearance of the ring, as seen in Dr. Lee's tele-

South.

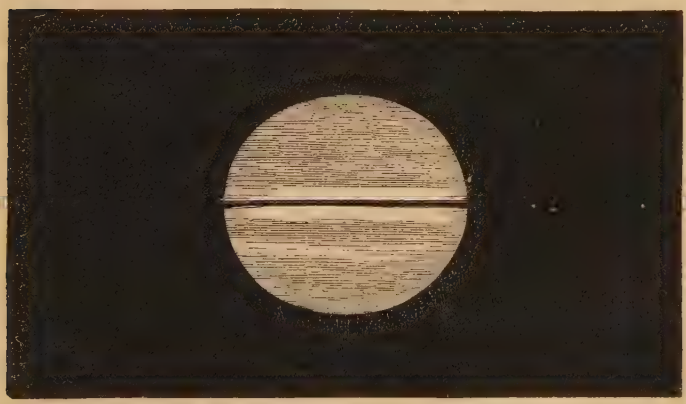


West. East.

North.

scope at Hartwell. I cannot say how far the inequalities in the ring were due to want of definition. The atmosphere was not in prime condition, and scarcely bore the power of 240 ; yet, when the definition seemed at its best by occasional glimpses, the inequalities were the most conspicuous.

South.



West. East.

North.

"No. 2 was taken at York on the morning of the 4th Dec.

with the 9-inch object-glass, which Messrs. Cooke and Sons have been preparing for my equatoreal. The excellence of its defining power may be judged of from the fact of its separating the dark streak across the planet into two parts, with an almost inconceivably fine line of light between, viz., the ring itself and its shadow. The breadth of the former could not have been much more than 0″·04.

"Only four satellites could be seen, viz., *Titan*, at some distance, and the three shown in the drawing, of which the outermost is *Tethys*, and the other two, probably, *Dione* and *Enceladus*.

"*Hartwell, near Aylesbury,*
December 11, 1861."

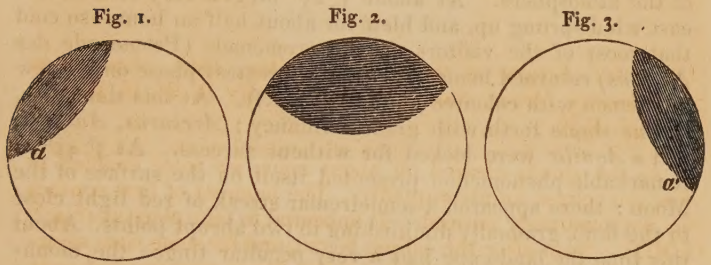
The Solar Eclipse of the 31*st December*, 1861, *observed at Kilkenny House, Sion Hill, Bath.* By R. W. H. Hardy, Esq., R.N.

As the clouds cleared off about noon, we were enabled to view the eclipse uninterruptedly. The moment of first contact was not accurately noticed. It appeared to take place at $1^h\ 45^m$ G.M.T. Soon after the eclipse began, and for some time afterwards, the overlapping surface of the Moon was covered over with a soft grey tint, which terminated on the advancing edge in a narrow band of deep purple. Concurrently with this purple band, there appeared in advance of the Moon's edge, but concentric with it, at a short distance, a bright gleam of light brighter than the solar disk. This light was separated from the Moon's edge by a narrow pale green shadow, which softened into the former. This is also the character of all shadows from objects on our Earth. At 2^h the Moon's edge undulated rapidly, while the Sun's edge remained comparatively tranquil. About this time also, the outline of the Moon appeared to form an irregular curvature, bulging out at the edge *a*, figure 1. This irregularity, however, diminished as the Moon advanced till she reached the central line, when it ceased; but began again to increase from this epoch till it reached a second maximum near the point *a′*, figure 3, at 3^h G.M.T. Before this, at $2^h\ 15^m$, a bright yellow-green light reflected from the Moon's edge and contiguous surface attracted our notice, which not only brought out our satellite in strong relief, but also showed the lunar surface beautifully foreshortened, especially so at $3^h\ 35^m$. With respect to the apparent undulations of the edges of the Sun and Moon, they were about equal when our satellite reached the line of centres, and at their

greatest difference of velocity when she attained the two opposite points *a* and *a'*, figures 1 and 3. When the moon reached the middle of the eclipse, as shown in figure 2, and by carefully excluding every ray of direct solar light, the Moon's edge was traceable upwards to a considerable distance from both cusps, as if illuminated by a faint twilight. The conclusion of the eclipse was not seen, owing to the thickness of the sky about that time.

My telescope is a 12-inch Newtonian reflector; the eyepiece I used on the occasion was an inverting one, and the power employed 60 times, which takes all the sun into the field. The projecting glass was a neutral tint, which does not materially affect the appearance of the colour of natural objects.

Inverted Images.



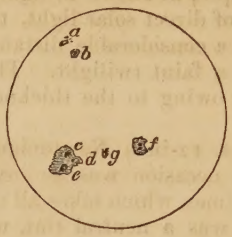
Eclipse of the Sun of 31*st December*, 1861, *observed at Nice.* By C. G. Talmage, late of the Greenwich and Regent's Park Observatories, Assistant to T. Coventry, Esq., 5 Tavistock Square.

(*Communicated by Mr. Hind.*)

The instrument used was a 5-foot Equatoreal, the stand and metal-work being constructed by Troughton and Simms; but the object-glass, which has a clear aperture of 4 inches, is of Munich manufacture.

Every precaution was taken that the first contact should be accurately observed; and the time, thermometer, and barometer observations are put by themselves, as being easier for reference.

At the total immersion of spot (*b*), it seemed suddenly to blaze forth, and quite a mauve tint was visible all round it. I



have only seen one instance on record of such an occurrence (Hind's *Solar System*, p. 65). The Moon's limb presented no irregularities. As the obscuration advanced to its greatest phase, a very sensible difference took place in the temperature of the atmosphere. At about $3^h\,25^m$ M.T. a very cold north-east wind sprung up, and blew for about half an hour—so cold that most of the visitors on the promenade (Promenade des Anglois) returned home, and at the greatest phase only a few gentlemen with coloured glasses were left. At this time, also, *Venus* shone forth with great brilliancy; *Arcturus*, *Antares*, and *α Aquilæ* were looked for without success. At $3^h\,45^m$, a remarkable phenomenon presented itself on the surface of the Moon: there appeared a semicircular streak of red light close to the limb, gradually diminishing to two abrupt points. About this time the landscape had a very peculiar tinge: the mountains at a great distance appeared of a deep blue tinge, and seemed to stand out with unnatural distinctness. Spot (*e*) was only just grazed by the Moon's limb. The Sun unfortunately setting before the eclipse had ended, we had not an opportunity of observing the time of last contact.

	h	m	s
Nice M.T. of first contact.....	2	27	22·80
Time of first contact of spot (*a*) ...	2	34	31
,, total immersion	2	34	45
Time of first contact of spot (*b*) ...	2	35	53
,, total immersion	2	36	36
Time of first contact of spot (*f*) ...	3	16	30
,, central bisection	3	17	16
,, total immersion	3	18	0
Time of total immersion of spot (*g*)	3	20	5
Time of first contact of spot (*c*) ...	3	21	40
,, total immersion	3	24	0

	h	m	s
Time of first contact of spot (*d*) ...	3	26	50
,, total immersion	3	29	30
Time of total emersion of spot (*c*)	3	38	35

Time.	Barom. m	Therm. in Shade. °	Therm. in Sun. °
0·0	30·327	68·8	93·1
0·30	30·327	69·8	90·0
1·15	30·315	67·7	75·5
2·20	30·305	65·7	73·3
2·40	30·300	64·5	72·5
3·10	30·300	62·2	65·0
3·30	30·300	60·3	60·8
3·50	30·300	59·0	59·0
4·5	30·300	57·8	58·8

P.S. The observations were made at the Grand Hotel Chauvain.

Occultations of Stars by the Moon. Observed by C. G. Talmage, Esq.

The observations were made at the Grand Hotel Chauvain, Nice, with a 5-foot equatoreal, aperture 4 inches.

Occultation of R *Aquarii* on Moon's dark limb, January 4, 1862:—

The dark limb was beautifully defined; the star appeared to be bisected by, or hung in, the Moon's limb for 8^s or 10^s.

Nice mean time of disappearance = $7^h\,34^m\,3^s{\cdot}00$.

Occultation of 103 *Tauri* on Moon's dark limb:—

Star disappeared instantaneously. January 12, 1862.

Nice mean time of disappearance = $9^h\,23^m\,40^s{\cdot}60$.

Occultation of 1 *Geminorum* on Moon's dark limb:—

Star very faint as it neared the Moon's limb. 1862, January 13.

Nice mean time of disappearance = $12^h\,32^m\,1^s{\cdot}00$.

ERRATA.

P. 38 (Mr. Lassell's Observations of the Transit of *Mercury*), *for* "Piazzi Stierna," *read* "Piazzi Slierna."

P. 40 (Prof. Chevallier's Account of the same Transit), immediately before Mr. Marth's Observations, *insert*, "But these observations, and especially those in declination, are regarded as sufficiently accurate only to show that the tables are nearly correct, the trembling of the Sun's limb rendering them uncertain."

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